

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	TITLE	
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENTS	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF FIGURES	x
	LISTS OF SYMBOLS	xiii
	LIST OF ABBREVIATIONS	xiv
	LIST OF APPENDICES	xv
1	INTRODUCTION	
	1.1 Research Background	1
	1.2 Objective of Research	3
	1.3 Scope of Research	3
2	LITERATURE REVIEW	
	2.1 Isomerization of Saturated Straight Alkane	4
	2.2 Solid Acid Catalysts for Alkanes Isomerization	5
	2.2.1 <i>Friedel-crafts</i> Catalysts	6
	2.2.2 Chlorinated Alumina	6
	2.2.3 Zirconia-based Catalyst	6
	2.2.4 Zeolite Material-based Catalyst	7

2.2.4.1	HZSM-5	9
2.3	<i>n</i> -Pentane Isomerization	10
2.4	Reaction Mechanism of <i>n</i> -Pentane Isomerization	12
2.4.1	Reaction Pathway of Monofunctional Mechanism	12
2.4.2	Reaction Pathway of Bifunctional Mechanism.	13
2.5	Role of Hydrogen on the Isomerization of Alkanes	14
2.6	Catalyst Preparation	16
3	EXPERIMENTAL	
3.1	Preparation of Catalysts	18
3.1.1	Preparation of HZSM-5	18
3.1.2	Synthesis of Zn/HZSM-5	18
3.1.3	Preparation of Zr(OH) ₄	19
3.1.4	Synthesis of Pt/SO ₄ ²⁻ -ZrO ₂	19
3.2	Characterization	19
3.2.1	X-Ray Diffraction (XRD) Analysis	19
3.2.2	BET Surface Area Analysis	20
3.2.3	Fourier Transform Infra Red (FTIR) Spectroscopy	20
3.2.4	Qualitative Analysis of Zn and Pt by Energy Dispersive X-ray (EDX)	21
3.2.5	Infra Red (IR) of Pyridine Adsorption	21
3.2.6	Ammonia Temperature Programmed Desorption (TPD)	22
3.3	Catalytic Testing	23
3.4	Formation of Protonic Acid Sites	23
4	RESULTS AND DISCUSSION	
4.1	Characterization of Catalysts	26
4.1.1	X-Ray Diffraction (XRD) Analysis	26
4.1.2	Fourier Transform Infra Red (FTIR) Spectroscopy	28
4.1.3	BET Surface Analysis	30
4.1.4	FESEM and EDX Analysis	30
4.1.5	Distribution of Acid Sites	32
4.1.6	Nature of Acidity	34

4.2	<i>n</i> -Pentane Isomerization on Zn/HZSM-5	38
4.3	Formation of Protonic Acid Sites	39
4.3.1	Hydrogen Molecule Originated Protonic Acid Sites	39
4.3.2	<i>n</i> -Pentane Originated Protonic Acid Sites	43
4.3.3	Hydrogenation of Chemisorbed Pyridine	49
5	CONCLUSION AND FUTURE WORK	
5.1	Conclusion	52
5.2	Future Work	53
	REFERENCES	54
	APPENDICES	60

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	The isomerization of <i>n</i> -pentane.	4
2.2	Acid sites on the surface of zeolite.	8
2.3	Structure of ZSM-5.	9
2.4	The possibilities of structure of Zn species in Zn/HZSM-5.	10
2.5	Monofunctional mechanism of <i>n</i> -pentane isomerization.	13
2.6	Bifunctional mechanism of <i>n</i> -pentane isomerization	14
2.7	Model for the generation of protonic acid sites of solid acid catalyst.	16
3.1	Formation of protonic acid sites apparatus.	25
4.1	XRD patterns of HZSM-5 and Zn/HZSM-5.	27
4.2	XRD pattern of Pt/SO ₄ ²⁻ -ZrO ₂ .	27
4.3	FTIR spectra of HZSM-5 and Zn/HZSM-5.	29
4.4	FTIR spectra of Pt/SO ₄ ²⁻ -ZrO ₂ .	29
4.5	FESEM image of Zn/HZSM-5	30
4.6	EDX analysis for Zn/HZSM-5	31
4.7	FESEM image of PSZ	31
4.8	EDX analysis for PSZ	32
4.9	Ammonia TPD plots of HZSM-5, Zn/HZSM-5 and Pt/SO ₄ ²⁻ -ZrO ₂ .	34

4.10	IR spectra of (a) HZSM-5 after treated at 623 K, (b) Pyridine adsorbed on HZSM-5, (c) Pyridine adsorbed on Zn/HZSM-5 at 423 K followed by removal of physisorbed of pyridine at 598 K.	35
4.11	A) IR spectra of pyridine adsorbed on Zn/HZSM-5 pretreated at 598 K followed by removal of physisorbed of pyridine at a) 423 K, b) 473 K, c) 523 K and d) 598 K. B) The fraction of acid sites after heating in the presence of hydrogen at different temperature.	36
4.12	The IR spectra of (a) $\text{Pt}/\text{SO}_4^{2-}\text{-ZrO}_2$ treated at 623 K and pyridine adsorbed on $\text{Pt}/\text{SO}_4^{2-}\text{-ZrO}_2$.	37
4.13	Activity and selectivity of Zn/HZSM-5 for <i>n</i> -pentane isomerization in the presence and absence of hydrogen.	39
4.14	IR spectra of pyridine adsorbed on Zn/HZSM-5. (A) Spectral changes when pyridine-preadsorbed sample was heated in hydrogen at b) 298 K, c) 323 K, d) 348 K, e) 373 K and f) 398 K. a) Before exposure to the hydrogen. (B) The change of spectrum (f) when hydrogen was removed at g) 323 K, h) 373 K, i) 423 K, j) 473 K, k) 523 K and l) 573 K.	41
4.15	The fraction of acid sites (A) after heating in the presence of hydrogen and B) removal of hydrogen at different temperature. White square and circle are Lewis and protonic acid sites before exposure to the hydrogen, respectively.	42
4.16	Proposed mechanism for formation of protonic acid sites from molecular hydrogen over solid acid catalyst.	43
4.17	IR spectra of pyridine adsorbed on Zn/HZSM-5. (A) Spectral changes when pyridine-preadsorbed sample was heated in dried <i>n</i> -pentane a) room temperature, b)	44

	323 K, c) 373 K, d) 473 K and e) 578 K. (B) Spectral changes when the sample of the spectrum (e) was heated in a removal of dried <i>n</i> -pentane at f) 323 K, g) 373 K, h) 473 K, i) 573 K and j) 623 K.	
4.18	The fraction of acid sites (A) after heating in the presence of <i>n</i> -pentane and B) removal of dried <i>n</i> -pentane at different temperature.	45
4.19	IR spectra of pyridine adsorbed on Pt/SO ₄ ²⁻ -ZrO ₂ . (A) Spectral changes when pyridine-preadsorbed sample was heated in dried <i>n</i> -pentane a) 373 K, b) 393 K, c) 423 K, d) 473 K, e) 528 K and f) 573 K. (B) Spectral changes when the sample of the spectrum (f) was heated in a removal of dried <i>n</i> -pentane at g) 373 K, h) 423 K, i) 473 K, j) 523 K and k) 573 K.	47
4.20	The fraction of acid sites (A) after heating in the presence of <i>n</i> -pentane and B) removal of dried <i>n</i> -pentane at different temperature.	48
4.21	Speculated mechanism for formation of protonic acid sites from <i>n</i> -pentane over solid acid catalyst.	48
4.22	Spectral changes for pyridine adsorbed on Zn/HZSM-5 caused by heating in hydrogen at a) room temperature, b) 373 K, c) 523 K and d) 573 K.	51

LIST OF SYMBOLS

θ	-	Angle
ε	-	Extinction coefficient
K	-	Kelvin
e^-	-	Electron

LIST OF ABBREVIATIONS

RON	-	Research Octane Number
ZSM-5	-	Zeolite Socony Mobil-Five
XRD	-	X-Ray Diffraction
FTIR	-	Fourier Transform Infra Red
TPD	-	Temperature-Programmed Desorption
CFR	-	Continuous Flow Reactor
L	-	Lewis
B	-	Brønsted
Py	-	Pyridine
BET	-	Brunauer, Emmet and Teller
n	-	Normal
i	-	Iso

LIST OF APPENDICES

APPENDICES	TITLE	PAGE
A	List of publication	60